

2006 STATEWIDE COMMERCIAL MUSSEL REPORT



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INTRODUCTION

This report contains mussel population and commercial harvest data collected during 2006, and compares harvest trends during the period 2002-2006. Activities described in this report were partially funded by the fee on commercial mussels and license sales associated with the commercial mussel program. Any person, firm or corporation who purchases or otherwise obtains freshwater mussels taken from Tennessee waters is required to pay the Tennessee Wildlife Resources Agency (TWRA) the amount equal to \$0.0145 per pound of mussel shells or \$0.0124 per pound of mussel (shell with meat) purchased or obtained. During 2006, TWRA received the following revenues associated with the sale of commercial musseling licenses and collection of the shell fee:

<u>TYPE LICENSE</u>	<u>NUMBER</u>	<u>REVENUE</u>
Resident Commercial Musseling	247	\$ 49,400
Non-Resident Commercial Musseling	3	\$ 3,000
Wholesale Mussel Dealer	15	\$ 6,500
Cultured Pearl	<u>2</u>	<u>\$ 2,000</u>
Total License	267	\$ 60,900
Shell Tax (accrued Jan. 1 to Dec. 31, 2006)		<u>\$ 31,174</u>
TOTAL REVENUE		<u>\$92,074</u>

The majority of freshwater mussel shells harvested in Tennessee were shipped to Japan, China and other countries where they were cut and polished into beads. These beads were inserted into marine oysters and freshwater mussels to form cultured pearls. According to Olson (2006), Tennessee continues to lead the United States in pearl and mother of pearl shell production. Tennessee's commercial mussel shell industry accounted for 69% of the total shell harvest value and 18% of the total value of natural gemstones produced in the United States during 2005.

During the early 1990's, commercial musseling employed as many as 3,000 people in Tennessee. However, biological problems affecting the survival and production of Japan's pearl producing oysters combined with other factors affecting the cultured pearl industry, Japanese and U.S. economies, reduced the market for Tennessee's mussel shells beginning in 1997 and continuing through 2002. Some shell exporters chose to ship only their highest quality shells during this period creating a narrower market with a lower demand for the standard quality shells that contributed to lower domestic wholesale shell prices. The decreased demand and lower prices paid for mussel shells caused a substantial decline in the number of mussel harvesters working in Tennessee. Reduced harvest pressure on the mussel resource allowed populations to begin recovering from a decade of intense harvest activity.

During the last century, the harvest of mussel shell has fluctuated according to market demands. Mussels were first harvested for the natural pearls they can produce, then as a source of raw material for buttons and mother of pearl inlay, and finally for the production of cultured pearl nuclei. Each rise and fall in demand has affected the quantity and quality of the resource available for harvest. In 2004, 2005 and 2006, China increased its use of shell bead pearl nuclei resulting in modest wholesale shell price increases and corresponding higher shell harvests.

Tennessee's quality commercial mussel stocks were primarily limited to Kentucky Reservoir (Hubbs 2006a). Kentucky Reservoir stretched 184.3 miles from Pickwick Dam at Tennessee River mile (TRM) 206.7 in Hardin County, TN to Kentucky Dam at TRM 22.4 near Gilbertsville, Kentucky. The Tennessee portion contained 1,971 shoreline miles and approximately 110,990 surface acres, ending at TRM 49.2 in Stewart County, TN. The main channel and over-bank widths varied from 0.25 to 2 miles. Information gathered from wholesale mussel dealers showed that most of the annual harvest was reported from Kentucky Reservoir. No other Tennessee waters appeared to contain mussel populations of sufficient quality, size and diversity to sustain a continuous commercial harvest. Mussel shell values fluctuated in relation to market demand, generally decreasing during 1997 to 2002, before sustaining annual increases from 2003 through 2006.

No commercial shell dealer or harvesters reported significant mussel “die-offs” to TWRA during 2006. Some wholesale mussel dealers did complain about the lower quality of shells being produced in the northern half of Kentucky Reservoir and the increase in “snout nosed mapleleaves” (*Quadrula apiculata*). They described the shells as having a “river grade” appearance, indicating that the periostracum in the umbonal area of the shell was damaged or missing, and the shells had a generally rougher exterior. The increased abundance of lower quality shells from this region could be attributed to the accumulation of Asian clam (*Corbicula fluminea*) shell shards, which now compose the top substrate layer on many of the clay bars where mussels are harvested (personal observation). The periostracum of mussels growing in these shell shards is worn away as the mussel moves through the substrate exposing the shell to degradation through dissolution, erosion, and staining.

Watts Bar Reservoir was also sampled during 2006 to ascertain the status of its mussel resources and locate potential site(s) for future collection of mussel tissue samples for contaminant analysis. Watts Bar Reservoir located on the upper Tennessee River between Chattanooga and Knoxville, runs between Watts Bar Dam (TRM 529.9), Rhea County, TN and Fort Loudon Dam (TRM 602.3), Loudon County, TN. It covers 72.4 river miles and stretches approximately 722 shoreline miles with 30,090 surface acres. Substrate ranged from silt to sand, gravel, cobble, and bedrock. Historically, this reservoir has not produced significant quantities of commercially valuable mussel shells and recent mussel recruitment has been very limited due to unknown factors. Survey efforts were coordinated with TWRA’s Environmental Services Division in order to locate mussel populations for contaminant monitoring.

During 2006, commercial musselers were restricted to harvesting only those individuals of the 10 freshwater mussel species listed below. Only individuals that will not pass through a ring with an inside diameter specified for that species as legal in Tennessee may be harvested. All other mussels were required to be returned immediately and unharmed to the bed from which they were taken.

<u>Mussel Species Listed for Harvest</u>	<u>Inside Ring Diameter in inches</u>
Pink heelsplitter (<i>Potamilus alatus</i>)	4.0
Washboard (<i>Megaloniais nervosa</i>)	4.0
River pigtoe (<i>Pleurobema cordatum</i>)	2 5/8
Lake pigtoe (<i>Fusconaia flava</i>)	2 5/8
Mapleleaf (<i>Quadrula quadrula</i>)	2 5/8
Snoot nose Mapleleaf (<i>Quadrula apiculata</i>)	2 5/8
Three ridge (<i>Amblema plicata</i>)	2 5/8
Elephant Ear (<i>Elliptio crassidens</i>)	2 5/8
Monkeyface (<i>Quadrula metanevra</i>)	2 3/8
Ebony (<i>Fusconaia ebena</i>)	2 3/8

METHODS and MATERIALS

The wholesale value of the mussel harvest was calculated by surveying active commercial mussel dealers' monthly records, and reviewing TWRA mussel receipts to collect price data for each shell category. Receipt data reports provided by TWRA's Data Management Division were used to calculate the total commercial harvest volume, species distribution and percent size composition (Clouse 2007). In 2006, the commercial mussel shell category known as "lake mix" was composed of the following species: threeridge (*Amblema plicata*), snootnose mapleleaf (*Q. apiculata*), mapleleaf (*Q. quadrula*), and lake pigtoe (*Fusconaia flava*). Multiplying the average annual price per pound by the estimated number of pounds harvested and then summing the categories derived the annual harvest value.

Commercial mussel population assessments were conducted on Kentucky Reservoir because it contains the most important commercial mussel beds. On Kentucky Reservoir, several techniques were employed to collect mussels from a variety of habitat types. Major collection efforts were directed toward sampling areas frequented by commercial harvesters. Because mussels exist as clumped, contiguous aggregations, stratified sampling techniques were employed. The reservoir was divided into three sections based on major hydrological characteristics. Specific sample locations were selected based on presence of significant mussel resources (density, diversity, and harvest activity). Watts Bar Reservoir was also sampled during 2006 to ascertain the status of its mussel resources with two sites sampled in the upper reach of the reservoir.

Each collection site was characterized according to location, substrate composition, water depth and any other relevant characteristics. The specific location of each site was recorded by river mile, proximity (left, right descending side or center), and latitude and longitude

(determined by a global position system). To aid data interpretation, population metrics were calculated with individual samples pooled for all collection methods and presented for each section.

SCUBA and surface supplied air compressor (Hookah system) were used to conduct surveys and collect samples in deep water environments (reservoirs and mainstream rivers). Before sampling a given area, a depth finder was used to analyze bottom characteristics and detect underwater obstructions that might impair collection efforts. In shallow water where samples could be collected by snorkeling or hand picking the aerial extent of the mussel bed (shoal) was visually determined. A representative sample was collected from the bed. Species composition was determined with timed collections. Effort was directed toward the collection of commercial mussel species consistent with methods employed by commercial mussel harvesters utilizing surface-supplied air diving equipment. Shallow water (<20 ft depth) site assessments consisted of ten free-swimming tethered dives with five minutes of active collecting per sample replicate. Because a larger sample size could be attained during timed collections, this was the preferred method. However, sites where depths were greater than 20 ft or swift current rendered this method impractical; timed dives of varied duration were employed to generate catch per unit effort data (CPUE).

All mussels collected were placed in mesh bags, brought to the surface for examination, and either retained for additional analyses or returned to the bed after enumeration. Mussels collected during population surveys were identified to species, enumerated, and recorded. Commercial species were measured (using rings of 2 3/8, 2 5/8 and 4.0 inches inside diameter according to current size limits for each species) to determine size distribution. Data were entered into a computer spreadsheet to tabulate species composition, size distribution, and relative abundance parameters. The legal-sized portion of the population was determined for all commercial species.

RESULTS and DISCUSSION

Commercial Shell Market Assessment

Tennessee's freshwater mussel shell market decreased slightly during 2006 (Figure 1), even though higher prices were noted for all shell categories (Figure 2). Monthly price data obtained from wholesale mussel dealers and TWRA mussel receipts were tabulated to compute average price paid for the major categories of shell. After harvest, shells are normally sized and grouped into the categories listed in Table 1. Shell values were only reported for green (live mussels), because the wholesale market for open (dead) mussel shell was very limited.

Information from TWRA's mussel receipt system, wholesale mussel dealer summaries, in addition to the wholesale price survey were used to compute the volume and value of the reported mussel harvest (Table 2). Tennessee wholesale mussel dealers reported purchasing 2,800,901 pounds (1,400 tons) of mussels from Tennessee waters during 2006. The harvest value was estimated at \$2,336,027 compared to \$2,404,375 paid for 3,386,254 pounds (1,693 tons) in 2005. Higher average prices were paid for all categories of mussels, and buyers were actively trading during the summer, thus the harvest was similar to 2005. Increased prices did not attract additional harvesters, the number of licensed harvesters decreased from 264 in 2005 to 250 in 2006 (Table 3). The average income per harvester increased from \$9,107 to \$9,344 per

harvester (Figure 1).

Average price of 2 3/8" ebony shells increased \$0.04 to \$0.61/lb, while the 2 3/4" increased \$0.14 to \$0.89/lb. Greater demand for lake mix shells drove the 2 5/8" price up \$0.22 from \$0.75 to \$0.97/lb, while 2 3/4" lake mix shells increased \$0.23 to \$1.10/lb (Figure 2). Minimum sized 4.0" lake washboard (*Megaloniais nervosa*) prices increased \$0.06 to \$1.06/lb. The lower priced 2 3/8" and 2 1/2" (ebony and monkey-face *Q. metanevra*) categories combined, comprised 41% of the harvest weight and 31% of the total value. Ebony shell in the 2 5/8" to 2 3/4" size comprised 15% by weight and 15% by value of the harvest. All size categories combined, the ebony shell produced 56% by weight and 46% by value of the 2006 harvest. Increased landings of lake mix categories (2 5/8" and 2 3/4") produced 39% of the harvest weight and 49% of the total value (Table 2). Lake grade washboards 4.0" and larger produced only 4.27% by weight and 5.42% by value of the 2006 shell harvest. River grade washboard production decreased from 109,010 pounds in 2005 to 12,509 in 2006. The market for colored shells (pinks) was very limited, producing only 0.14% by weight and 0.19% by value. These shifts in species and sizes of commercial shell landings were attributed to a general increase in market demand for lake mix shells. Weighted average wholesale price paid to harvesters (\$0.83/lb in 2006), has maintained a steady increase during the last four years (Figure 2).

According to wholesale dealer receipts, 98% of the 2006 Tennessee mussel harvest came from Kentucky Reservoir (Appendix A). An analysis of Kentucky Reservoir's harvest data and size distribution by species group showed 73% by weight of the ebony shells were between 2 3/8" and 2 1/2", compared to 27% at 2 5/8" and larger. The lake mix group continued to benefit from reduced harvest pressure, with the weight of 2 3/4" shells (58%) exceeding the 2 5/8" (42%) by 16%. Lake grade washboards were entirely made up of 4.0" grade shells with none reported as => 5.0". Mussel shells imported from other states equaled 219,072 pounds, and comprised 7.2% by weight of the total Tennessee market.

Because of their longevity and relatively slow growth, commercial mussel populations subjected to intense harvest pressure are susceptible to being "cropped off" (very low percentage of legal-sized and larger individuals present in a population). When this occurs, the shell industry has to fill orders with higher percentages of the more abundant, smaller categories of mussel shell. Conversely, when harvest pressure is reduced, viable commercial mussel populations recoup allowing increased recruitment into the larger size classes. Variation in the size distribution of the shells harvested can also be attributed to shifts in demand for different shell products. This is evident when comparing the distribution of the percent weight by size category data during 2002 to 2006. During this period, the combined percent weight of the 2 3/8" and 2 1/2" categories fluctuated from 36% to 41%. Changing market demands along with the sliding 1/16-inch annual size limit increase limited the availability of larger-sized washboard shells (≥ 4 ") which remained $\leq 7\%$ (Table 4). Recent changes incorporated into TWRA's mussel receipt allowed the 2 1/2", 2 3/4", 3" and 4" data to be captured as distinct size categories.

During the late 1980's through 1995, intense harvest pressure on Kentucky Reservoir's mussel stocks resulted in mussels being taken almost immediately after attaining legal size. TWRA's concern for declining percentages in the adult portion of mussel populations led to recommendations to increase the legal size limit on washboards from 3 3/4" to 4", and increasing the size limit on lake mix shells from 2 5/8" to 2 3/4". In April 1999 the Tennessee Wildlife Resources Commission increased the size limit on washboards from 3 3/4" to 4", staggering the

increase in 1/16" increments over a four-year period beginning in 2000 and ending in 2003 when the size limit would reach 4". The size limit on lake mix shells remains at 2 5/8", however reduced demand and lower harvest pressure has allowed expansion of the 2 3/4" size class.

Mussel Population Assessments

The Tennessee portion of Kentucky Reservoir was sampled at six commercial mussel sites (five open water sites and one site on the closed to harvest mussel management area) during 2006. Forty discrete five-minute timed collections were made along with 10, 10-minute samples from open harvest waters and 10, five-minute samples from closed harvest waters: for a total of 350 minutes of collection effort. Thirty-two freshwater mussel (unionid) taxa were collected totaling 1,960 individuals, along with two exotic bivalve species (Asian clam, *Corbicula fluminea* and zebra mussel, *Dreissena polymorpha*) (Appendix B).

Section I – Tennessee River Mile 49.2 to 82.5. Paris Landing/White Oak Creek. This section is dominated by reservoir over-bank habitat with silt, sand, Asian clam shells, and clay substrates, with gravel along the shorelines. During years of high commercial shell demand, mussel harvest pressure has reached ten harvesters per river mile. Harvest pressure is spread across the shallow (<10 - 15 ft) bars, shoreline habitats, old creek channels and river channel wall (depth >20 - 50 ft). Commercially valuable mussel species are found amongst the clay and gravel bars, scattered in the bays, along shorelines, and more concentrated near and along sloping channel walls. Densities rarely exceed ten mussels per square meter away from the main channel. Mussel recruitment is primarily limited to areas with well-established mussel populations. Mussels in this section of the lake exhibit the fastest shell growth rate, but overall densities are low. Few recent records of endangered mussel species are known from this section. Two productive sites were sampled during 2006, producing 802 individuals representing eight of the ten commercial mussel species (Table 5). The four most abundant species are all commercially important; the ebony shell (*F. ebena*) 44%, mapleleaf 25% (*Q. quadrula* and *Q. apiculata* combined), threeridge (*A. plicata*) 15%, and washboard (*M. nervosa*) 14%. Approximately 20% of the commercial species collected were legal-size or larger, down from 32% in 2005. Timed sampling resulted in an average collection rate of 8.02 mussels per minute up from 6.0 in 2005. Four zebra mussels (Appendix C) were encountered during 100 minutes of sampling during 2006 compared to none in 2005. The Asian clam was abundant at both sites, with their dead shells comprising a majority of the top layer of substrate.

Section II - TRM 82.5 to 111.1. Harmons Creek/New Johnsonville/Duck River. This section is a transitional area with both lotic and lentic habitats. Mussel harvest pressure has reached ten harvesters per river mile. Harvest pressure is dispersed over the bays, submerged creek channels, over-bank bars, channel walls and old riverbed at depths from zero to > 50 ft. Mussel populations are dispersed throughout the varied habitats, and reach maximum densities (> 100 mussels per square meter) in the river channel. Population recruitment is high in and near the main river and creek channels resulting in colonies expanding from these habitats. Substrate composition varies from silt, sand, clay, to gravel, Asian clam shells, cobble, and bedrock. Several recent endangered mussel species records (pink mucket, *Lampsilis abrupta*) exist for this section. Two sites were sampled during 2006; one in waters open to commercial harvest and one from closed waters. Seven of the ten commercial mussel species were collected from the open water site totaling 303 individuals during 50 minutes of sampling effort. The collection rate was

6.06 mussels per minute up from 4.85 in 2005. The closed harvest site yielded all ten commercial species during 50 minutes of sampling effort totaling 412 individuals with a CPUE of 8.24 down from 12.5 in 2005 (Table 5). Two commercially important species composed 54% of the open water population (threeridge 31%, and washboard 24%), followed by ebony (20%), and mapleleaves (13%). Approximately 34% of the commercial species collected from open waters were legal-sized or larger (ebony was 82% legal) compared to 26% from closed waters. It is understood that localized mussel poaching along with high juvenile mussel recruitment on the closed water site depressed the legal sized portion of the commercial population (F. Couch, personal communication). No zebra mussels were collected during 100 minutes of combined sampling effort during 2006. The Asian clam was abundant at all sites, with their dead shells comprising a portion of the top layer of substrate.

Section III - TRM 111.1 to 206.7. Located south of the mouth of the Duck River to Pickwick Dam. Lotic habitats dominate this section. Harvest pressure averages less than one harvester per river mile. However, harvest pressure can be intense around the shallow (10 - 25 ft deep) sand/gravel bars and around mainstream islands. Some harvest also occurs in the larger bays of this reach. Mussel populations are primarily found in and near the old river channel, and to a lesser extent, along the shorelines. Maximum densities (> 100 mussels per square meter) and recruitment levels are found outside the navigation channel in the shallow gravel deposits on the inside river bends and at the head and tail areas of mainstream islands. Many recent endangered mussel records for several different species exist for this section (Hubbs 2006b). Two commercial mussel population assessments were performed in this section during 2006; each site was sampled by collecting five discrete 10-minute samples, 100 minutes of total effort. Nine of the ten commercial mussel species were collected, totaling 443 individuals. The collection rate was 4.43 mussels per minute with 21% legal size or larger. Ebony shell comprised 80% of the sample population followed by monkeyface (11%). Twenty-three zebra mussels were encountered during 100 minutes of sampling (0.23 per minute) compared to six during 60 minutes (0.10 per minute) of sampling during 2005. The Asian clam was abundant at all sites, with their dead shells comprising a portion of the top layer of substrate.

Section I, II, & III combined - Reservoir wide sampling of open waters resulted in the collection of 1,548 mussels representing the ten commercial taxa at an average collection rate of 6.2 mussels per minute, 23% of which were legal sized or larger down from 38% in 2005. It was noted that only two percent of the washboards sampled were of legal size (3 of 187), up from one percent in 2005. The low percentage of legal sized washboards was attributed to the impact of previous years (2001 to 2004) illegal harvest and sale of sub-legal sized washboards documented by TWRA and USFWS law enforcement investigations (F. Couch, personal communication); and the minimum size limit increase to four inches instituted in 2003. Commercial harvest of Tennessee's mussel shells did not exceed 2,000 tons during 2002 to 2006. Market fluctuation and lower demand has allowed mussel populations to recover somewhat from more than a decade of intense harvest activity. However, the last four consecutive years of harvest pressure above 1,200 tons per year has caused a decrease in the percentage of legal-sized mussels in the Kentucky Reservoir population (Figure 3).

The ebony shell is the foundation species of Tennessee's commercial shell market. On average, the ebony shell comprised 54% by weight and 45% by value of the harvest during the last five years, while the population remained above 30% legal-sized individuals. However, it

did drop from 61% to 33% legal-sized from 2005 to 2006. In contrast, the legal-sized washboard population has remained very low during the last five years. It averaged less than 3% legal-sized shells during 2002-06, while averaging 6% by weight and 10% by value of the harvest. The 1/16" per year (2000 to 2003) incremental size limit increase, and illegal harvest of smaller than 4.0" washboards during 2001 to 2004, are considered contributing factors to its decline in the harvest.

The lake mix group (three-ridge, maple-leaf, and pigtoe) with legal sizes averaging 20% for the period 2002-06, has not been as sensitive to harvest pressure as the washboard. During the last five years, the lake mix group averaged 35% by weight and 43% by value of Tennessee's commercial shell market. However, it did experience a drop from 25% legal-sized in 2005 to 15% in 2006. The inverse relationship between the tons of shell harvested and the percent legal-sized remaining, suggests the washboard population remains overharvested while the ebony and lake mix groups are also affected by increased harvest pressure (Table 6). Because abundance of the adult portion of the population is negatively correlated with harvest pressure, some populations (washboard and lake mix) remain below the market's demand and the reservoir's carrying capacity. Current size limits appear adequate to protect reproduction; however, previous year's harvests may affect recruitment.

Zebra mussels were encountered with greater frequency in 2006 compared to previous years. A total of 27 individuals were collected during 350 minutes of commercial mussel population sampling for a collection rate of 0.08 per minute compared to six individuals collected during 2005 (collection rate = 0.02 per minute). Seventy zebra mussels were collected during 210 minutes of collecting effort (0.33 per minute) in December 2006, while performing the mussel survey and relocation associated with the Tennessee Department of Transportation's Danville Ferry ramp project located in Section I at TRM 77.8 adjacent to the Houston County, TN shoreline.

Watts Bar Reservoir - Two sites were sampled in the upper reach of Watts Bar Reservoir during 2006 to ascertain the status of its mussel resources and locate potential site(s) for future collection of mussel tissue samples for contaminant analysis. Survey efforts were coordinated with TWRA's Environmental Services Division in order to locate mussel populations for contaminant monitoring. Substrate ranged from silt to sand, gravel, cobble, and bedrock. Historically, this reservoir has not produced significant quantities of commercially valuable mussel shells and recent mussel recruitment has been very limited due to unknown factors. Sixty minutes of sampling effort were spent at two sites next to Browder Island near TRM 597.3. Five Unionid species totaling 30 individuals were collected at a CPUE of 0.5 mussels per minute and one live zebra mussel at a CPUE of one per hour (Table 7). One individual of the pistol-grip (*Tritogonia verrucosa*) \leq five years old evidenced recent recruitment. One commercial species, elephant ear (*Elliptio crassidens*) comprised 56% of the sample population, 100% of which were equal to or greater than legal size, followed by threehorned wartyback (*Obliquaria reflexa*) at 27% abundance.

SUMMARY

Work performed under TWRA Commercial Musseling project number 7363 addressed Strategic Plan Problem I. Strategies 1, 2 and 4. License sales and mussel fee revenue associated with the commercial mussel program garnered **\$92,074** during 2006. Tennessee's freshwater mussel shell market decreased slightly during 2006, even though higher prices were noted for all shell categories, and buyers were actively trading during the summer. Tennessee wholesale mussel dealers reported purchasing 2,800,901 pounds (1,400 tons) of mussels from Tennessee waters during 2006. The harvest value was estimated at \$2,336,027 compared to \$2,404,375 paid for 3,386,254 pounds (1,693 tons) in 2005. However, increased prices did not attract additional harvesters, the number of licensed harvesters decreased from 264 in 2005 to 250 in 2006. The average income per harvester increased from \$9,107 to \$9,344 per harvester.

Average price of 2 3/8" ebony shells increased from \$0.57 to \$0.61/lb, while the 2 3/4" increased from \$0.75 to \$0.89/lb. Greater demand for lake mix shells drove the 2 5/8" price up \$0.22 from \$0.75 to \$0.97/lb, while 2 3/4" lake mix shells increased from \$0.87 to \$1.10/lb. Minimum sized 4.0" lake washboard prices increased from \$1.00 to \$1.06/lb. These shifts in species and sizes of commercial shell landings were attributed to a general increase in market demand for lake mix shells. Weighted average wholesale price paid to harvesters (\$0.83/ lb in 2006) has steadily increased during the last four years.

According to wholesale dealer receipts, 98% of the 2006 Tennessee mussel harvest came from Kentucky Reservoir. An analysis of Kentucky Reservoir's harvest data and size distribution by species group showed 73% by weight of the ebony shells were between 2 3/8" and 2 1/2", compared to 27% at 2 5/8" and larger. The lake mix group continued to benefit from reduced harvest pressure, with the weight of 2 3/4" shells (58%) exceeding the 2 5/8" (42%) by 16%. Lake grade washboards were entirely made up of 4.0" shells with none reported as 5.0". Mussel shells imported from other states equaled 219,072 pounds, and comprised 7.2% by weight of the total Tennessee market.

The Strategic Plan objective of increasing/maintaining commercial mussel populations to a level where $\geq 15\%$ are above legal-size limits was met for the ebony and lake mix categories. Although, sustained harvest pressure caused declines in both ebony shell (61% in 2005 to 33% in 2006) and lake mix (25% in 2005 to 15% in 2006) populations. Kentucky Lake washboards failed to reach the objective, measuring only 2.0% above legal-size, due to heavy harvest pressure during 1999-2000, the new (in 2003) 4" minimum size limit and the illegal harvest of washboards ≤ 4 " during 2001 to 2004. Strategic Plan Problem VII. Strategy 2 dealing with the introduced aquatic nuisance species *Dreissena polymorpha* (zebra mussel) was partially accomplished in Appendix C, via cooperation with the U.S. Army Corps of Engineers and Tennessee Valley Authority (R. Tippit 2005). Lack of funding restricted monitoring efforts to only those that coincided with scheduled freshwater mussel investigations.

Even during periods of decreased harvest activity, law enforcement continues to play a critical role in the management and protection of Tennessee's valuable mussel resources. History of the commercial shell industry's buying practices indicates that market demand for a particular category of shell can trump any regulation against the harvesting of said shell. The viability of the commercial mussel populations can be assured only through adherence to adequate minimum size regulations and maintaining the integrity of closed waters for population comparisons and

species protection. Minimum shell size regulations are based on conservative age and growth estimates, which allow brooding female mussels several years to spawn before reaching the legally harvestable size limit.

RECOMMENDATIONS

The commercial mussel program continues to be inadequately funded. In order to monitor and protect this valuable renewable resource, many man-hours of biological and law enforcement effort are required to guard against illegal take, overexploitation, and habitat degradation. Therefore, in order for this program to meet its fiduciary and resource management responsibilities, the following recommendations are offered:

1. Seek increased revenue to fund fully the existing commercial mussel program. The current shell fee paid to TWRA by wholesale dealers has not increased since it was levied in July 1991 at \$0.0124/lb for live mussels (shell with meat) and \$0.0145/lb for open shells (shells without meat). In order to balance the commercial mussel program's deficit, TWRA's Commercial Mussel strategic plans have recommended an increase in the shell fee for more than 10 years. TWRA has experienced a drastic decline in the number of harvester licenses sold since the fee was levied (down from average of 1,440/year during 1990-95 to 244/year for last 5 years). The fee on commercial mussels and shells should be increased to a level sufficient to fund the commercial mussel program (approximately \$0.10 per pound at 2006 harvest level).
2. Extend the Cedar Creek Sanctuary to include Kelly's Island and Tennessee River Mile 145.0. Combined brail and dive samples indicate that the majority of the mussel stocks in this reach lie within a bed that extends from TRM 145 - 141.0. This extension would protect a population of the rare spectaclecase mussel (*Cumberlandia monodonta*) (Garner, 1991) and better protect the existing mussel bed. By making these two additions to the sanctuary system, not only would rare and endangered species be protected, but several commercial species would also be afforded a greater opportunity to reproduce without being disturbed. This additional protection would enhance mussel recruitment that could help replenish populations adjacent to the protected zones through dispersion of juvenile mussels by their fish hosts.
3. Close the Cumberland River to commercial mussel harvesting due to the low recruitment rate and lack of viability of the fishery. The Cumberland River reservoirs have not produced significant shell harvests during the last five years (average 0.75% of annual harvest weight). Water quality and flow alterations resulting from emergency repair operations to Wolf Creek Dam are scheduled to continue for the next seven years. The warmer temperatures predicted for this period may allow for increased recruitment that could enhance the future commercial shellfishery. Closing the commercial mussel harvest on the Cumberland River would afford the population the opportunity for expansion and create the possibility of a rejuvenated fishery in the future.
4. Continue to monitor the mussel resource through commercial industry, population surveys, and laboratory analysis. These surveys provide critical trend data on the species composition, condition, volume of the mussel harvest, and population status.

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FIGURES

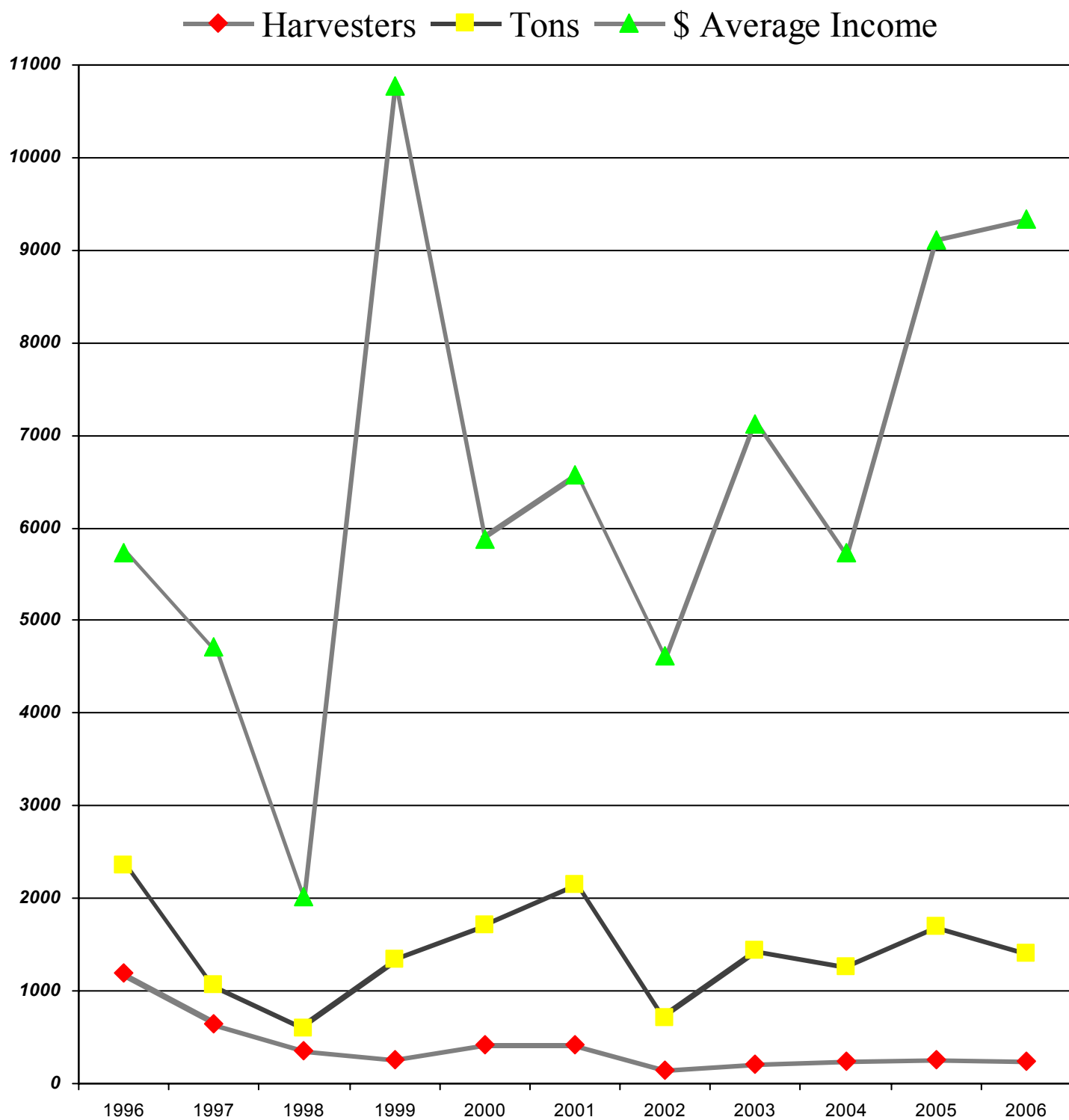


Figure 1. Tennessee mussel shell harvest trends, 1996 - 2006.

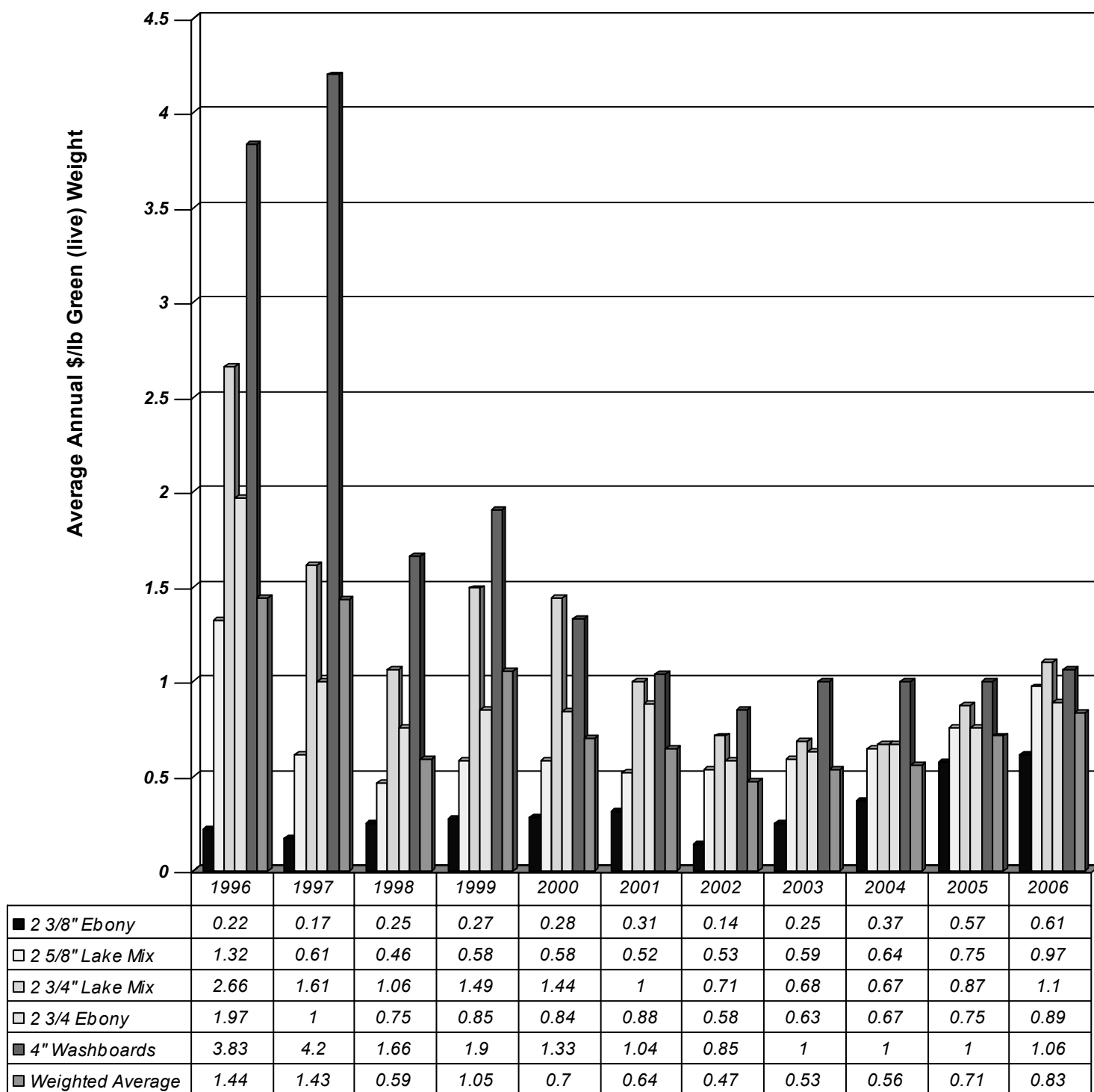


Figure 2. Tennessee wholesale shell price trends, 1996 - 2006.

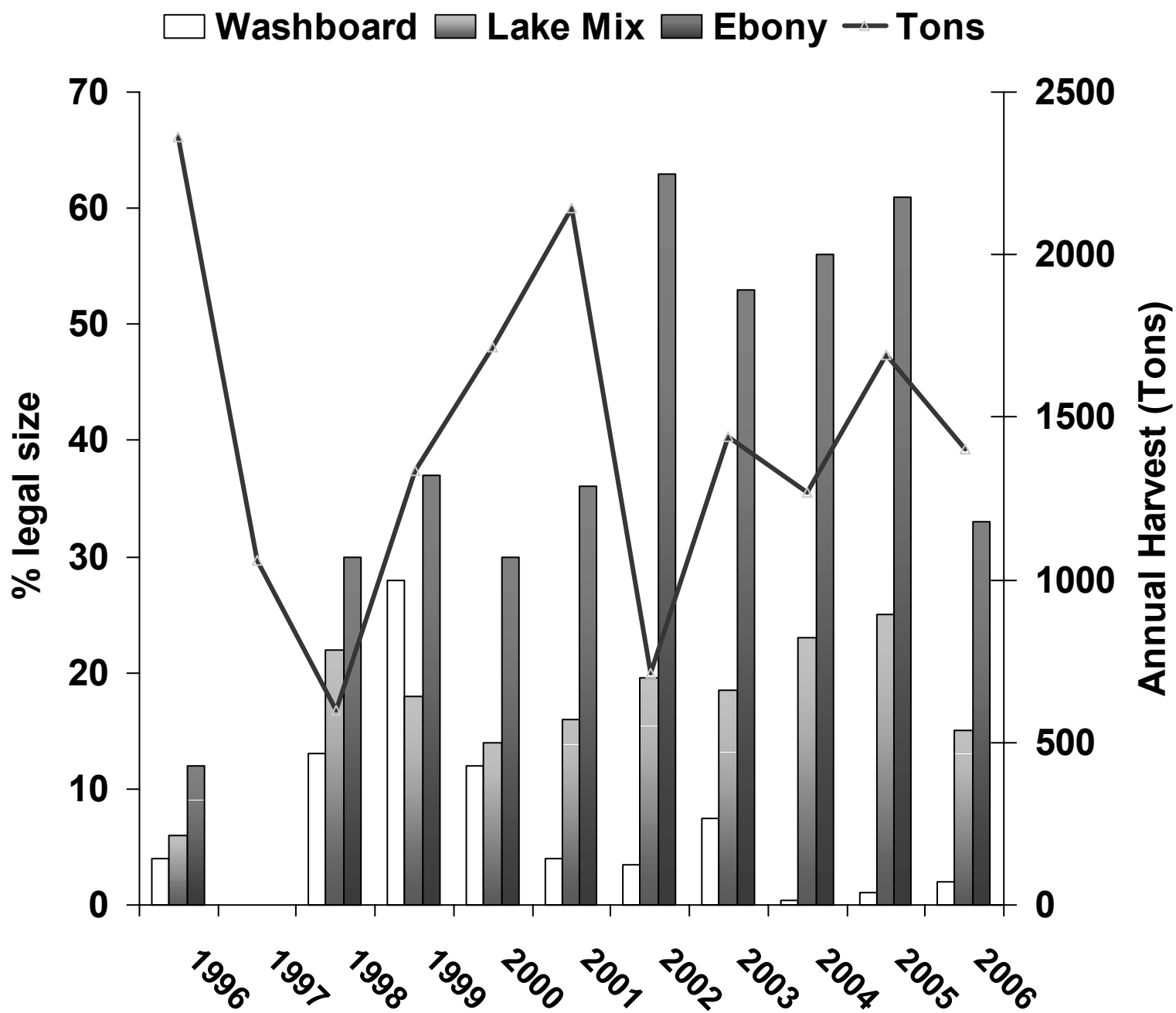


Figure 3. Legal sized mussel shell in Kentucky Reservoir population, 1996 - 2006.

TABLES

Table 1. Average wholesale price paid for various categories of commercial shell during 2006.

CATEGORY	CONDITION	AVERAGE PRICE (\$/LB)	SPECIES
LAKE MIX 2 5/8"	GREEN	\$0.97	<i>A. plicata, F. flava, Q. quadrula</i> <i>Q. apiculata</i>
LAKE MIX 2 3/4"	GREEN	\$1.10	<i>A. plicata, F. flava, Q. quadrula</i> <i>Q. apiculata</i>
EBONY 2 3/8"	GREEN	\$0.61	<i>F. ebena</i>
EBONY 2 1/2"	GREEN	\$0.63	<i>F. ebena</i>
EBONY 2 5/8"	GREEN	\$0.74	<i>F. ebena</i>
EBONY 2 3/4"	GREEN	\$0.89	<i>F. ebena</i>
LAKE WASHBOARD 4.0"	GREEN	\$1.06	<i>M. nervosa</i>
LAKE WASHBOARD 5.0"	GREEN	\$1.50	<i>M. nervosa</i>
RIVER WASHBOARD 4.0" & Larger	GREEN	\$1.25	<i>M. nervosa</i>
PINK HEELSPLITTER 4.0" & Larger, Grade #1	OPEN	\$1.12	<i>P. alatus</i>

GREEN = Shell with meat

OPEN = Shell without meat

Table 2. 2006 wholesale commercial shell harvest by size category, as estimated from Tennessee waters.

	WEIGHT LBS	PERCENT WEIGHT	ESTIMATED VALUE	PERCENT VALUE
CATEGORY				
Lake Grade Washboards 4.0" to 4.5"	119,552	4.27%	\$126,725	5.42%
Lake Grade Washboards 5.0"	0	0.00%	\$0	0.0%
River Grade Washboards ≥ 4.0"	12,509	0.45%	\$20,390	0.87%
Pink Heelsplitter ≥ 4.0"	3,954	0.14%	\$4,428	0.19%
Ebony 2 3/8"	514,353	18.36%	\$313,755	13.43%
Ebony 2 1/2"	633,940	22.63%	\$399,382	17.10%
Ebony 2 5/8"	313,544	11.19%	\$232,023	9.93%
Ebony $\geq 2 \frac{3}{4}$"	118,675	4.24%	\$105,621	4.52%
Lake Mix 2 5/8"	454,679	16.23%	\$441,039	18.88%
Lake Mix $\geq 2 \frac{3}{4}$"	629,695	22.48%	\$692,665	29.65%
Total	2,800,901	100%	\$2,336,027	100%
Tons	1,400			

Table 3. Tennessee commercial mussel shell industry volume and value, 2002-2006.

Year	2002	2003	2004	2005	2006
Harvesters	144	215	247	264	250
Dealers	11	13	14	15	15
Tons	714	1,439	1,267	1,693	1,400
Millions \$	\$0.66	\$1.5	\$1.4	\$2.4	\$2.3
Shell Fee	\$15,759	\$35,049	\$31,786	\$32,985	\$31,174
Average Wholesale price/lb	\$0.47	\$0.53	\$0.56	\$0.71	\$0.83

Table 4. Tennessee's commercial mussel shell harvest size class distribution by weight, 2002-2006.

	YEAR				
SIZE CLASS	2002	2003	2004	2005	2006
2 3/8"	13.6%	10.6%	17.1%	21.1%	18.4%
2 1/2"	22.6%	24.9%	24.1%	21.2%	22.6%
2 5/8"	35.6%	33.3%	27.6%	32.4%	27.4%
2 3/4"	16.9%	26.1%	26.1%	18.4%	26.7%
3 7/8"					
3 15/16"	5.7%				
=>4"	1.6%	5.1%	5.0%	6.8%	4.9%

Table 5. Summary of commercial mussel species data, Kentucky Reservoir sections I, II, and III.

Section I - Paris Landing	Legal	Sub-Legal	Total	%Legal	%Abundance
Amblema plicata	18	102	120	15%	15%
Elliptio crassidens	1	0	1	100%	0%
Fusconaia ebena	131	225	356	37%	44%
Fusconaia flava	3	6	9	33%	1%
Megaloniaias nervosa	0	112	112	0%	14%
Potamilus alatus	0	4	4	0%	0%
Pleurobema cordatum					
Quadrula quadrula					
Quadrula apiculata	4	196	200	2%	25%
Quadrula metanevra					
Sites Sampled			2		
CPUE = mussels per minute	1.57	6.45	8.02		
Total	157	645	802	20%	100%
<i>Dreissena polymorpha</i>			4		

Section II - Camden	Legal	Sub-Legal	Total	%Legal	%Abundance
Amblema plicata	32	61	93	34%	31%
Elliptio crassidens			0	0%	0%
Fusconaia ebena	50	11	61	82%	20%
Fusconaia flava	4	9	13	31%	4%
Megaloniaias nervosa	2	70	72	3%	24%
Potamilus alatus	10	15	25	40%	8%
Pleurobema cordatum			0		
Quadrula quadrula	3	19	22	14%	7%
Quadrula apiculata	3	14	17	18%	6%
Quadrula metanevra			0		
Sites Sampled			1		
CPUE = mussels per minute	2.08	3.98	6.06		
Total	104	199	303	34%	100%
<i>Dreissena polymorpha</i>			0		

Table 5. Continued.					
Section III – Savannah	Legal	Sub-Legal	Total	%Legal	%Abundance
Amblema plicata	2	2	4	50%	1%
Elliptio crassidens	1	14	15	7%	3%
Fusconaia ebena	74	281	355	21%	80%
Fusconaia flava					
Megaloniaias nervosa	1	2	3	33%	1%
Potamilus alatus	0	2	2	0%	0%
Pleurobema cordatum	1	2	3	33%	1%
Quadrula quadrula		1	1	0%	0%
Quadrula apiculata	3	7	10	30%	2%
Quadrula metanevra	11	39	50	22%	11%
Sites Sampled			2		
CPUE = mussels per minute	0.93	3.50	4.43		
Total	93	350	443	21%	100%
<i>Dreissena polymorpha</i>			23		

Section I, II, & III combined	Legal	Sub-Legal	Total	%Legal	%Abundance
Amblema plicata	52	165	217	24%	14%
Elliptio crassidens	2	14	16	13%	1%
Fusconaia ebena	255	517	772	33%	50%
Fusconaia flava	7	15	22	32%	1%
Megaloniaias nervosa	3	184	187	2%	12%
Potamilus alatus	10	21	31	32%	2%
Pleurobema cordatum	1	2	3	33%	0%
Quadrula quadrula	3	20	23	13%	1%
Quadrula apiculata	10	217	227	4%	15%
Quadrula metanevra	11	39	50	22%	3%
Sites Sampled			5		
CPUE = mussels per minute	1.42	4.78	6.19		
Total	354	1194	1548	23%	100%
<i>Dreissena polymorpha</i>			27		

Table 5. Continued.					
Closed Mussel Mgmt Area	Legal	Sub-Legal	Total	%Legal	%Abundance
Amblema plicata	48	54	102	47%	25%
Elliptio crassidens	1	1	2	50%	0%
Fusconaia ebena	38	161	199	19%	48%
Fusconaia flava	2	2	4	50%	1%
Megaloniaia nervosa	3	18	21	14%	5%
Potamilus alatus	7	13	20	35%	5%
Pleurobema cordatum	3		3	100%	1%
Quadrula quadrula	0	9	9	0%	2%
Quadrula apiculata	3	46	49	6%	12%
Quadrula metanevra	2	1	3	67%	1%
Sites Sampled			1		
CPUE = mussels per minute	2.14	6.10	8.24		
Total	107	305	412	26%	100%
<i>Dreissena polymorpha</i>			0		

Table 6. Kentucky Reservoir percentage legal-sized commercial mussels by category, 2006.

	TWRA Population Samples, Sections I, II and III combined			
	N	Open Waters Legal-Sized	N	Closed waters Legal-Sized
Ebony $\geq 2 \frac{3}{8}$"	772	33%	199	19%
Lake Mix $\geq 2 \frac{5}{8}$"	489	15%	118	45%
Washboards ≥ 4"	187	2%	21	14%

Table 7. Watts Bar Reservoir commercial mussel species data.

Watts Bar Reservoir at Browder Island TRM 597.3 left descending side	Non- Commercial	Legal	Sub- Legal	Total	%Legal	%Abundance
Amblema plicata				0		
Elliptio crassidens		17		17	100%	56%
Fusconaia ebena				0		
Fusconaia flava				0		
Megaloniais nervosa				0		
Obliquaria reflexa	8			8		27%
Potamilus alatus		2		2	100%	7%
Pleurobema cordatum				0		
Quadrula pustulosa	2			2		7%
Quadrula quadrula				0		
Quadrula apiculata				0		
Quadrula metanevra				0		
Tritogonia verrucosa	1			1		3%
Sites Sampled				2		
CPUE = mussels per minute		0.32	0.00	0.5		
Total	11	19	0	30	100%	100%
<i>Dreissena polymorpha</i>				1		

APPENDICES

APPENDIX
A
2006 Wholesale Mussel Dealer
& Receipt Report Summary Data

Mussel Harvest by Lake 1/1/2006 through 12/31/2006

Lake BARKLEY RESERVOIR											
shl	meat	g500	g450	g400	g375	g300	g275	g268	g250	g238	Shell Total
LEB	G	0	0	0	0	0	13	0	116	0	129
LML	G	0	0	0	0	0	333	217	0	0	550
LWB	G	0	0	236	0	0	0	0	0	0	236
R3R	G	0	0	0	0	0	1438	0	0	0	1438
REB	G	0	0	0	0	0	0	0	5	0	5
REB	O	0	0	0	0	0	0	0	0	127	127
RLM	G	0	0	0	0	0	128	0	0	0	128
RPT	G	0	0	0	0	0	30	34	0	0	64
RWB	G	0	0	8456	0	0	0	0	0	0	8456
RWB	O	0	0	10	0	0	0	0	0	0	10
Totals		0	0	8702	0	0	1942	251	121	127	11143

Lake KENTUCKY RESERVOIR											
shl	meat	g500	g450	g400	g375	g300	g275	g268	g250	g238	Shell Total
3K	O	0	0	0	0	0	0	0	0	608	608
BL	O	0	0	0	0	74	0	0	0	0	74
DEA	G	0	0	0	0	0	0	0	2032	121	2153
L3R	G	0	0	0	0	2074	0	0	0	0	2074
L3R	O	0	0	0	0	0	7108	0	0	0	7108
LEB	G	0	0	173	111	130	115114	204389	620264	224426	1164607
LEB	O	0	0	114	0	0	198	339	4164	5651	10466
LHS	O	0	0	96	0	0	0	0	0	0	96
LML	G	0	0	63	16	1901	610902	449422	1197	62	1063563
LML	O	0	0	0	0	4600	735	853	0	160	6348
LTR	G	0	0	0	0	0	0	36	0	0	36

LWB	G	0	136	109956	104	9	1310	201	0	522	112238
LWB	O	0	25	178	0	0	0	0	0	16	219
MF	O	0	0	0	0	0	0	166	0	0	166
MEF	G	0	0	0	0	0	0	95	0	0	95
PB	O	0	0	0	0	0	0	0	28	0	28
PHS	G	41	0	1612	0	0	0	0	0	0	1653
PHS	O	0	0	1034	0	0	0	0	0	0	1034
R3R	G	0	0	0	0	0	298	0	0	0	298
REB	G	0	0	0	0	0	67	107500	1306	206281	315154
REB	O	0	0	0	0	0	0	218	0	8502	8720
RMF	G	0	0	19	0	0	0	406	0	33637	34062
RMF	O	0	0	0	0	0	0	0	0	152	152
RMG	G	0	0	0	0	0	0	0	0	2	2
RWB	G	0	0	3995	0	0	0	0	0	0	3995
ZZZ	G	0	0	48	0	0	0	0	4127	238	4413
ZZZ	O	0	0	0	0	0	0	0	0	52	52
Totals		41	161	117288	231	8788	735732	763625	633118	480430	2739414

Lake NICKAJACK RESERVOIR

shl	meat	g500	g450	g400	g375	g300	g275	g268	g250	g238	Shell Total
LEB	G	0	0	0	0	0	0	230	306	28289	28825
LEB	O	0	51	1375	0	0	0	0	374	5445	7245
LEM	G	0	0	0	0	0	0	0	21	0	21
LHS	G	0	0	73	0	0	0	0	0	0	73
LHS	O	0	63	1035	0	0	0	0	0	0	1098
LML	G	0	0	0	0	0	69	4107	0	0	4176
LML	O	0	0	0	0	0	0	5	0	0	5
LTR	G	0	0	0	0	0	0	2	0	0	2
LTR	O	0	0	0	0	0	0	3	0	0	3
LWB	G	0	117	8472	0	0	0	0	0	57	8646

LWB	O	0	0	319	0	0	0	0	0	0	319
REB	G	0	0	0	0	0	0	0	0	489	489
REB	O	0	0	0	0	0	0	0	0	124	124
Totals		0	231	11274	0	0	69	4347	701	34404	51026

Lake OUT-OF-STATE

	shl	meat	g500	g450	g400	g375	g300	g275	g268	g250	g238	Shell Total
3K	O	0	0	0	0	0	0	0	0	0	734	734
BFB	O	0	0	14843	0	0	0	0	0	0	0	14843
BL	O	0	0	0	0	556	0	0	0	0	0	556
BLE	O	0	0	100	0	2352	50	0	0	0	0	2502
BLF	O	0	0	21	0	0	0	0	0	0	0	21
BLU	O	0	0	0	0	0	0	0	2308	0	0	2308
L3R	G	0	0	0	0	5456	17904	0	0	0	0	23360
L3R	O	0	0	0	0	10981	14677	0	0	500	0	26158
LEB	G	0	0	0	0	0	2982	6532	29069	8331	0	46914
LEB	O	0	0	0	0	0	852	0	409	10	0	1271
LML	G	0	0	0	0	0	2509	968	2832	0	0	6309
LML	O	0	0	0	0	0	37685	18	0	0	0	37703
LWB	G	0	14	7620	0	0	0	0	0	0	0	7634
LWB	O	0	26	526	0	0	0	0	0	0	0	552
MF	O	0	0	0	0	0	0	0	498	652	0	1150
MKF	O	0	0	0	0	0	4312	1576	0	0	0	5888
NH	G	0	0	0	0	0	0	0	0	265	0	265
OTR	O	0	911	9170	0	0	277	0	66	0	0	10424
PB	O	0	0	0	0	0	0	0	0	28	0	28
R3R	G	0	0	0	0	0	551	12	0	0	0	563
R3R	O	0	0	0	0	1540	83	0	0	0	0	1623
RB	O	0	0	724	0	0	0	0	0	0	0	724
REB	G	0	0	0	0	0	0	0	338	6465	6570	13373

RFB	O	0	30	10	0	0	0	0	64	0	104
RLM	O	0	0	0	0	0	0	0	300	0	300
RML	O	0	17	0	0	0	400	0	0	0	417
RNH	G	0	0	0	0	0	0	0	284	0	284
RNH	O	0	0	0	0	0	0	0	74	0	74
RPB	O	0	0	0	0	0	0	0	60	0	60
RWB	G	0	0	3021	0	0	0	0	0	0	3021
RWB	O	0	809	7597	0	0	0	0	0	0	8406
ZZZ	G	0	0	0	0	0	0	0	0	27	27
ZZZ	O	0	0	180	0	0	284	0	330	0	794
Totals		0	1807	43812	0	20885	82566	9942	43206	16172	218390
<hr/>											
Report total		41	2199	181076	231	29673	820309	778165	677146	531133	3019973

**APPENDIX
B
Freshwater Mussel Species
Collected From Kentucky Reservoir
During 2006 Sampling and Observations**

2006 mussel species collected from Kentucky Reservoir all sites/observations. 1 = live.

	Species	
1	<i>Anadonta suborbiculata</i>	1
2	<i>Pyganodon grandis</i>	1
3	<i>Utterbackei imbecillis</i>	1
4	<i>Amblema plicata</i>	1
5	<i>Arcidens confragosa</i>	1
6	<i>Cumberlandia monodonta</i>	
7	<i>Cyclonaias tuberculata</i>	1
8	<i>Cyprogenia stegaria</i>*	
9	<i>Elliptio crassidens</i>	1
10	<i>Ellipsaria lineolata</i>	1
11	<i>Fusconaia ebena</i>	1
12	<i>Fusconaia flava</i>	1
13	<i>Lampsilis abrupta</i> *	1
14	<i>Lampsilis cardium</i>	
15	<i>Lampsilis ovata</i>	1
16	<i>Lampsilis teres</i>	1
17	<i>Lasmigonia complanata</i>	
18	<i>Leptodea fragilis</i>	1
19	<i>Ligumia recta</i>	1
20	<i>Megalonaias nervosa</i>	1
21	<i>Obliquaria reflexa</i>	1
22	<i>Plectomerus dombevanus</i>	1
23	<i>Plethobasus cooperianus</i>*	1
24	<i>Plethobasus cyphus</i>	
25	<i>Pleurobema rubrum</i>	
26	<i>Pleurobema cordatum</i>	1
27	<i>Pleurobema sintoxia</i>	
28	<i>Potamilus alatus</i>	1
29	<i>Potamilus ohioensis</i>	1
30	<i>Ouadrula apiculata</i>	1
31	<i>Ouadrula c. cylindrica</i>	1
32	<i>Ouadrula metanevra</i>	1
33	<i>Ouadrula nodulata</i>	1
34	<i>Ouadrula pustulosa</i>	1
35	<i>Ouadrula ouadrula</i>	1
36	<i>Toxolasmus parvus</i>	1
37	<i>Toxolasmus lividus</i>	
38	<i>Truncilla donaciformis</i>	1
39	<i>Truncilla truncata</i>	1
40	<i>Tritogonia verrucosa</i>	1
	TOTAL	32
	EXOTIC SPECIES	
	<i>Dreissena polymorpha</i>	1
	<i>Corbicula fluminea</i>	1

***Federal Endangered species**

**APPENDIX
C
Zebra Mussel Distribution
In Tennessee**

Since the first documented collection of the zebra mussel in Tennessee occurred on the Tennessee River at Savannah, Hardin Co., Tennessee during February 1992, reports of one to several individuals have become more numerous. Clusters of zebra mussels have been discovered on the lock walls of most TVA and Army Corps of Engineer facilities open to commercial navigation traffic on the Tennessee and Cumberland rivers. Barge and boat traffic are believed to be the primary vectors of dispersion of this exotic species. Summer water temperature extremes, fish predation and water chemistry characteristics may be limiting the expansion of the zebra mussel population in some areas, particularly the lower Tennessee River.

Zebra mussel sightings continue to be reported by commercial musselers working the Kentucky Reservoir portion of the Tennessee River system. While it has yet to develop densities that endanger the native mussel fauna, frequency of occurrence and number of individuals are on the increase as of 2006. Zebra mussel densities in the upper Tennessee River system increased during the late 1990's through 2001. An established colony of zebra mussels below Watts Bar Dam, at TRM527.1, increased from 600 to just over 5,000 per square meter in late 2001. At TRM558.2, zebra mussels reached an even higher density of 23,166 per square meter. A large population was also noted below Chickamauga Dam, at TRM 470.0. Density at this site was estimated at 11,613 per square meter (anonymous, 2002). However, the hot and dry summers of 2004 and 2005 significantly reduced these populations. Only two live zebra mussels were encountered at nine TWRA freshwater mussel assessment sites below Watts Bar Dam during 2005, resulting in a CPUE of 0.45 zebra mussels per hour.

Zebra mussels have colonized the Mississippi River along the western border of Tennessee. They are abundant and attached to surfaces of concrete and rock bank stabilization structures below the water line. Some native mussels collected from the Mississippi River have been covered with zebra mussels.

TWRA personnel will continue to monitor zebra mussel populations through cooperation with commercial harvesters, and other government agencies. While accurately predicting what ultimate effect this exotic species will have on native mussel stocks and other aquatic species is difficult, the potential for devastation does exist.